Specifically Designed Constructed Wetlands: A Novel Treatment Approach for Scrubber Wastewater

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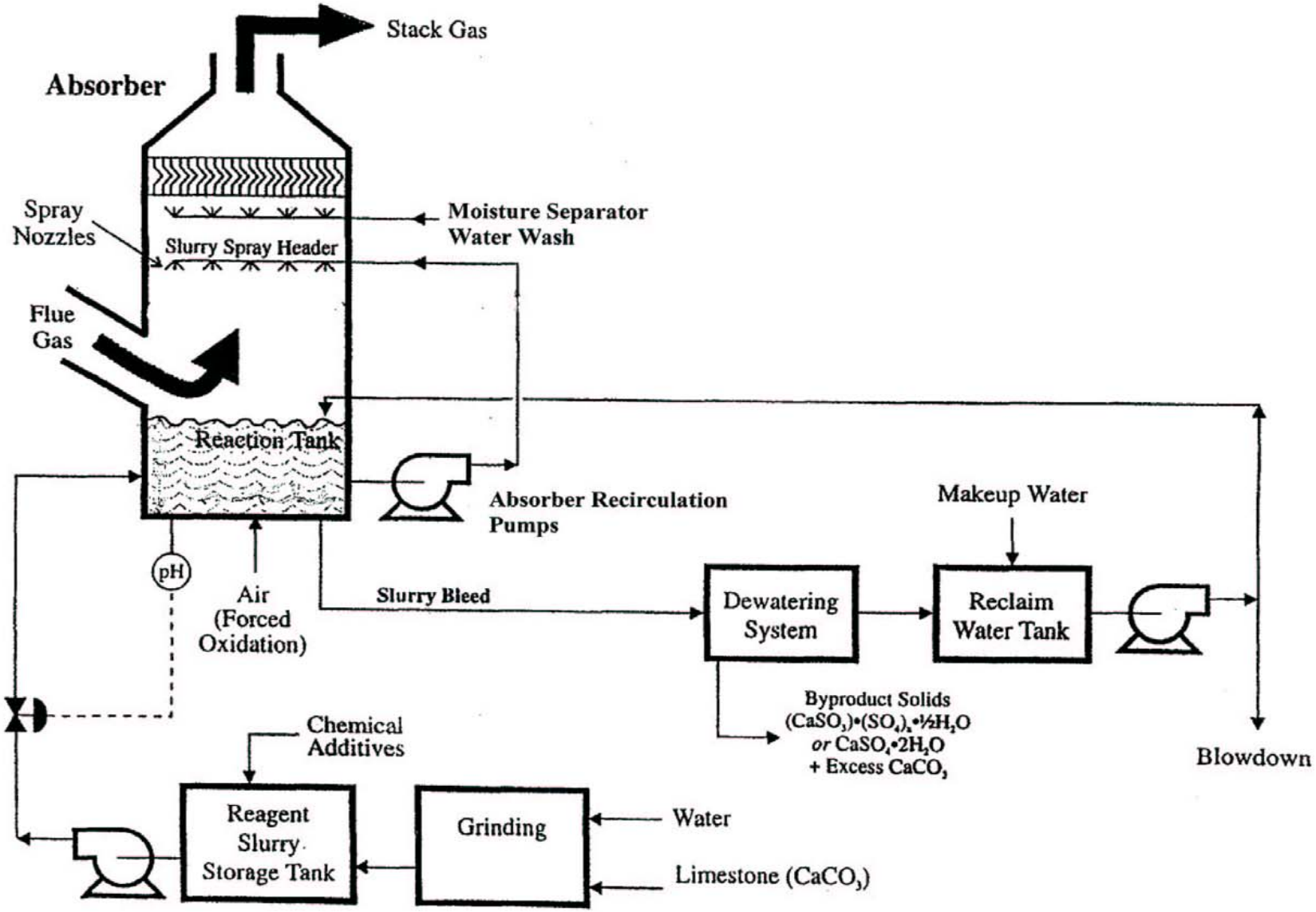
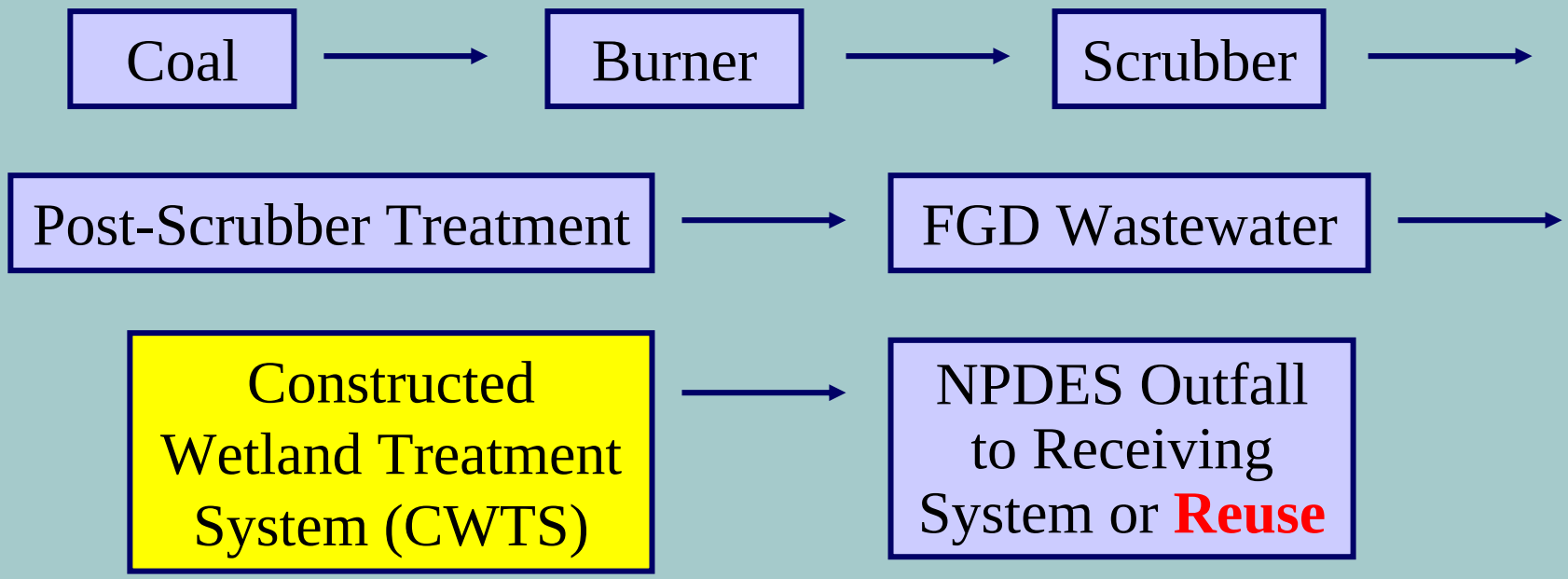
Objectives

- **Evaluate specifically designed pilot-scale constructed wetland treatment systems for treatment of targeted constituents in scrubber (FGD) wastewater from coal-fired power plants.**
- **Decrease targeted constituents in FGD wastewater for discharge (NPDES and CWA) or reuse.**

Wet Limestone FGD System (Scrubber)



Factors that Influence Flue Gas Desulfurization (Scrubber) Wastewater



Risk

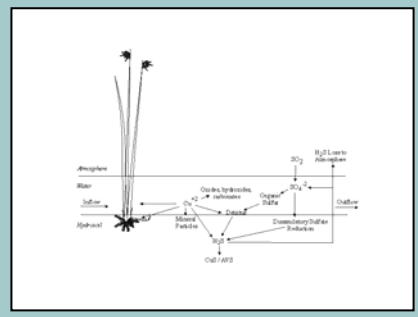
Water Quality Standards – Toxicity Tests

Approach

- **Task 1: Measure performance of a pilot-scale constructed wetland treatment system (CWTS) in terms of decreases in targeted constituents in FGD wastewater.**
- **Task 2: Determine how observed performance is achieved in CWTS.**
- **Task 3: Assess performance of CWTS in terms of decreased bioavailability of targeted elements (outflow toxicity and sediment toxicity).**

Literature

Theoretical Modeling



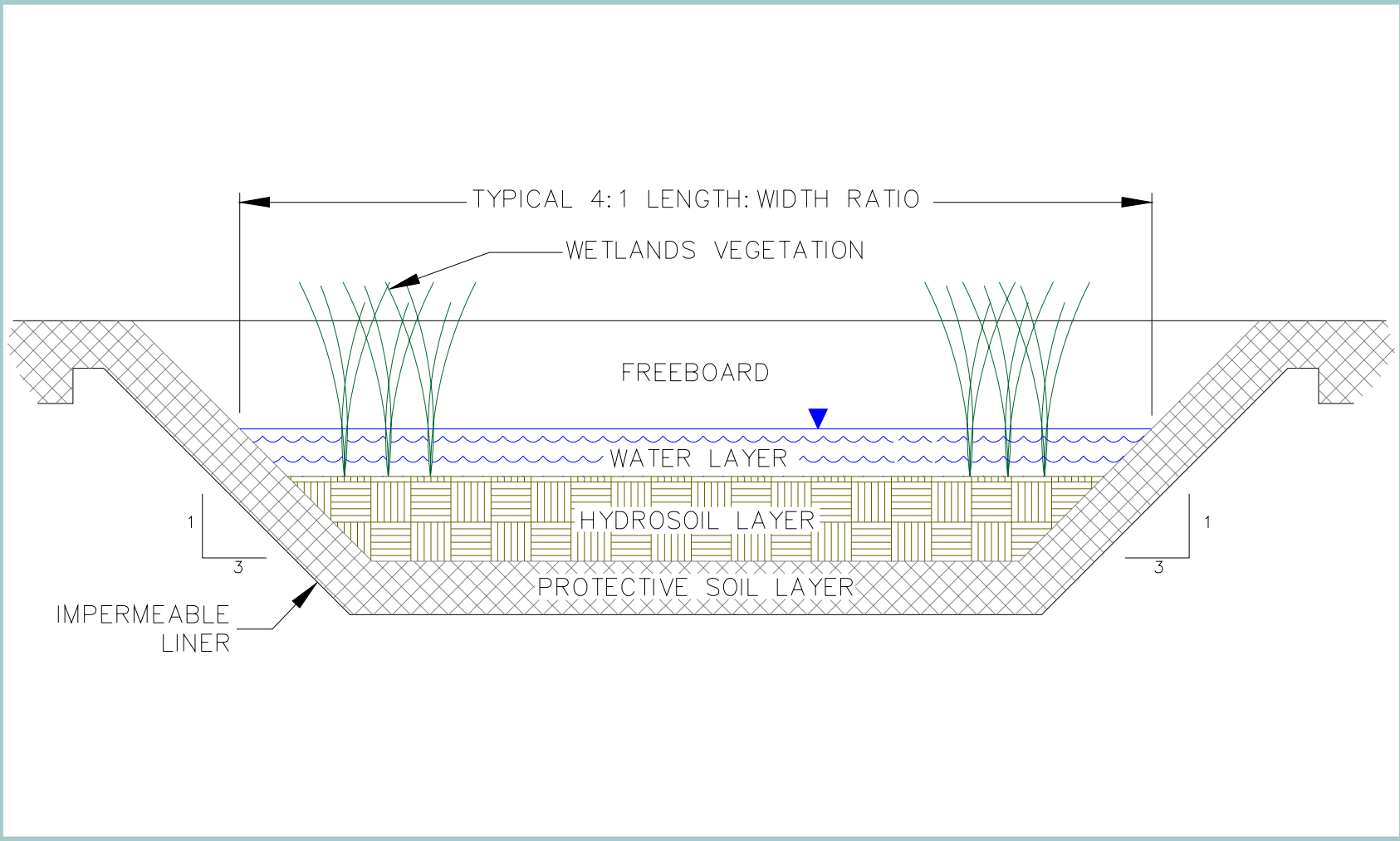
Pilot-Scale Physical Model of CWTS

Full-scale System

What Are Constructed Wetland Treatment Systems (CWTS)?

Systems carefully designed to “treat” (transfer or transform) constituents in wastewater in order to decrease the environmental risk these constituents may pose in receiving systems (downstream lakes, reservoirs, rivers, streams, etc.) or in order to make the water suitable for reuse.

CWTS Design


TYPICAL 4:1 LENGTH:WIDTH RATIO
WETLANDS VEGETATION
FREEBOARD
WATER LAYER
HYDROSOIL LAYER
PROTECTIVE SOIL LAYER
1
3
1
3
IMPERMEABLE LINER

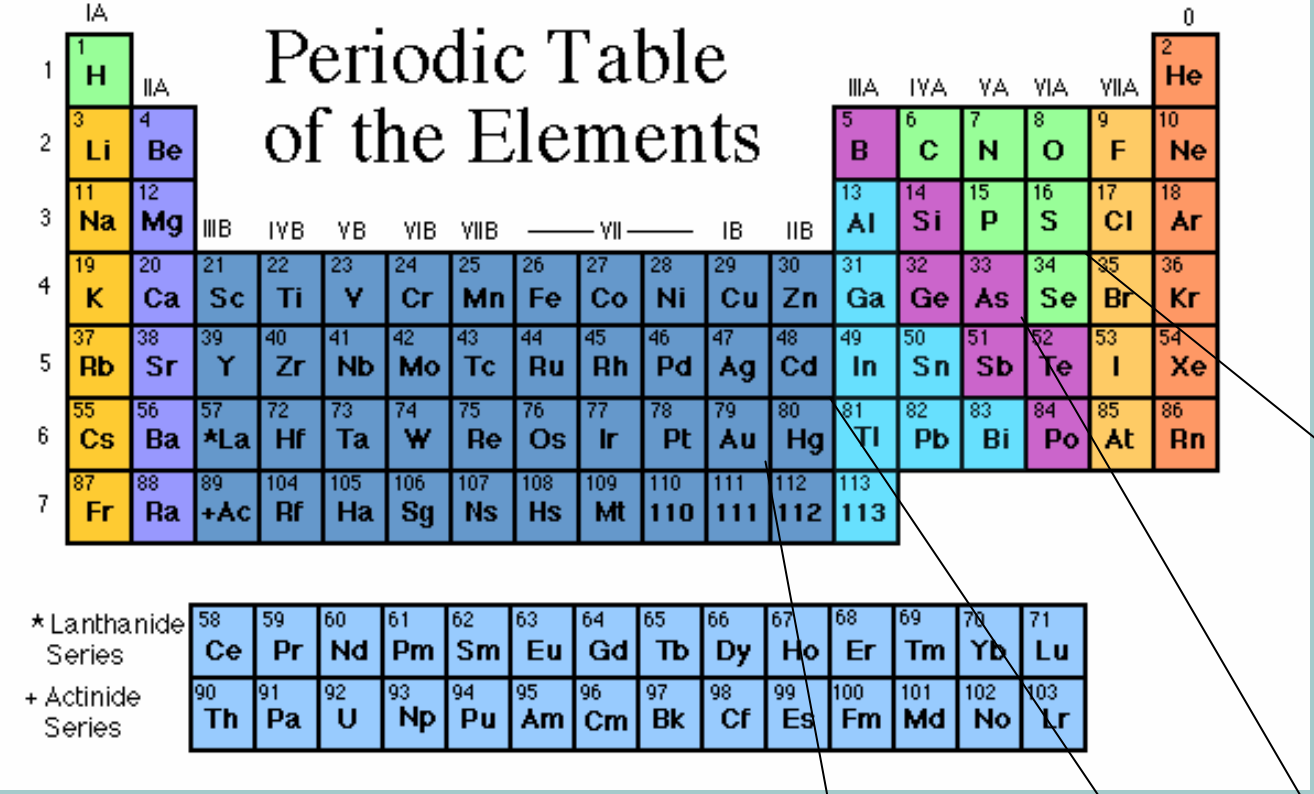
Constructed Wetland Treatment System

Features of Constructed Wetland Treatment Systems

- Largely self-maintaining
- Treat multiple constituents; wide range of concentrations
- Design for seasonal variations
  - e.g., annual plant dieback renews sediment binding surfaces
- Permitted as wastewater treatment systems

Major Benefits

- Typically cost 50% to 90% less than conventional treatment systems
  - Low construction cost
  - Low operating expense
- Provide effective wastewater treatment (achieve NPDES requirements)
- Support of regulatory community
- Water conservation and reuse

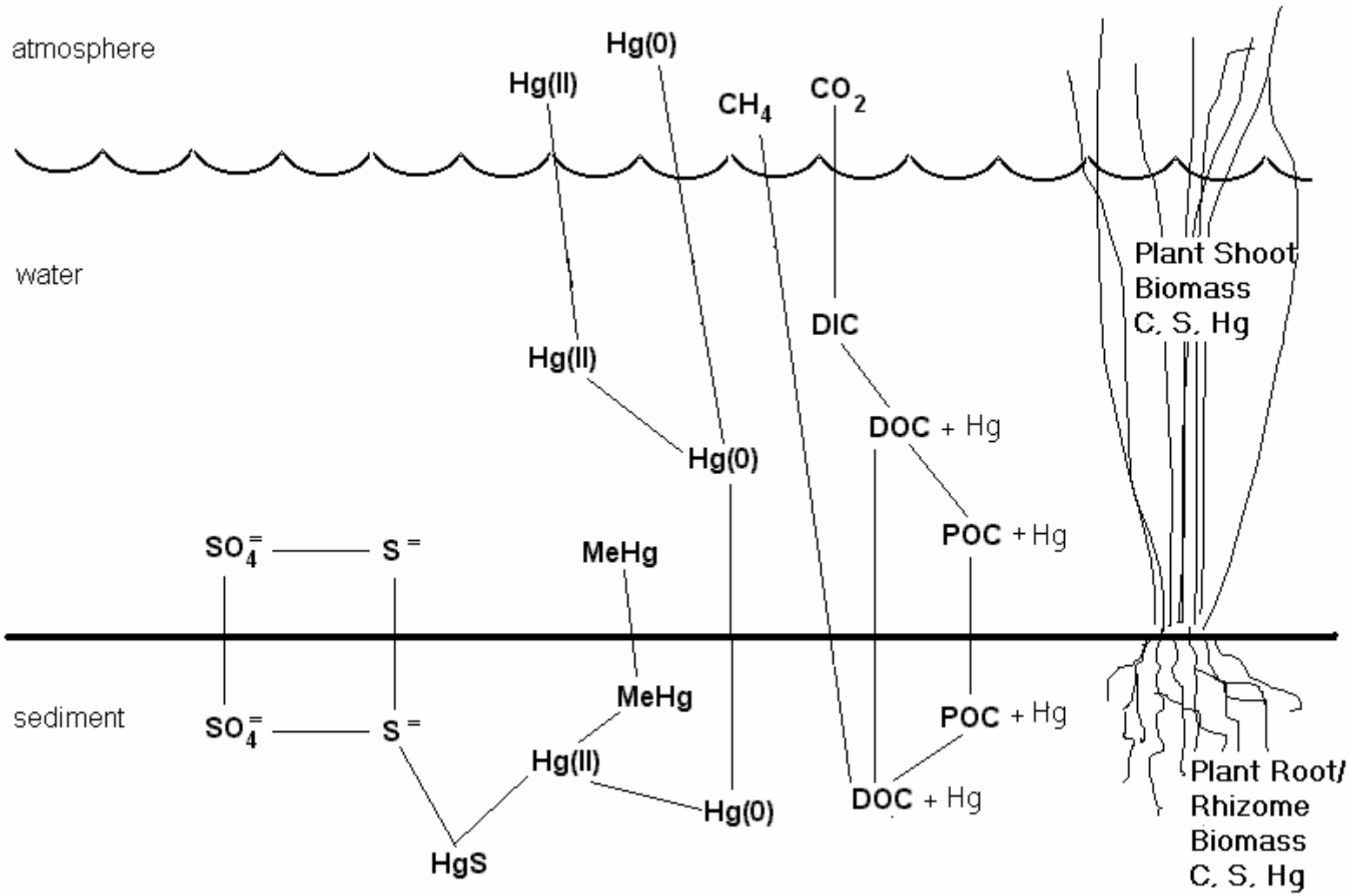


Targeted Elements in FGD Wastewater

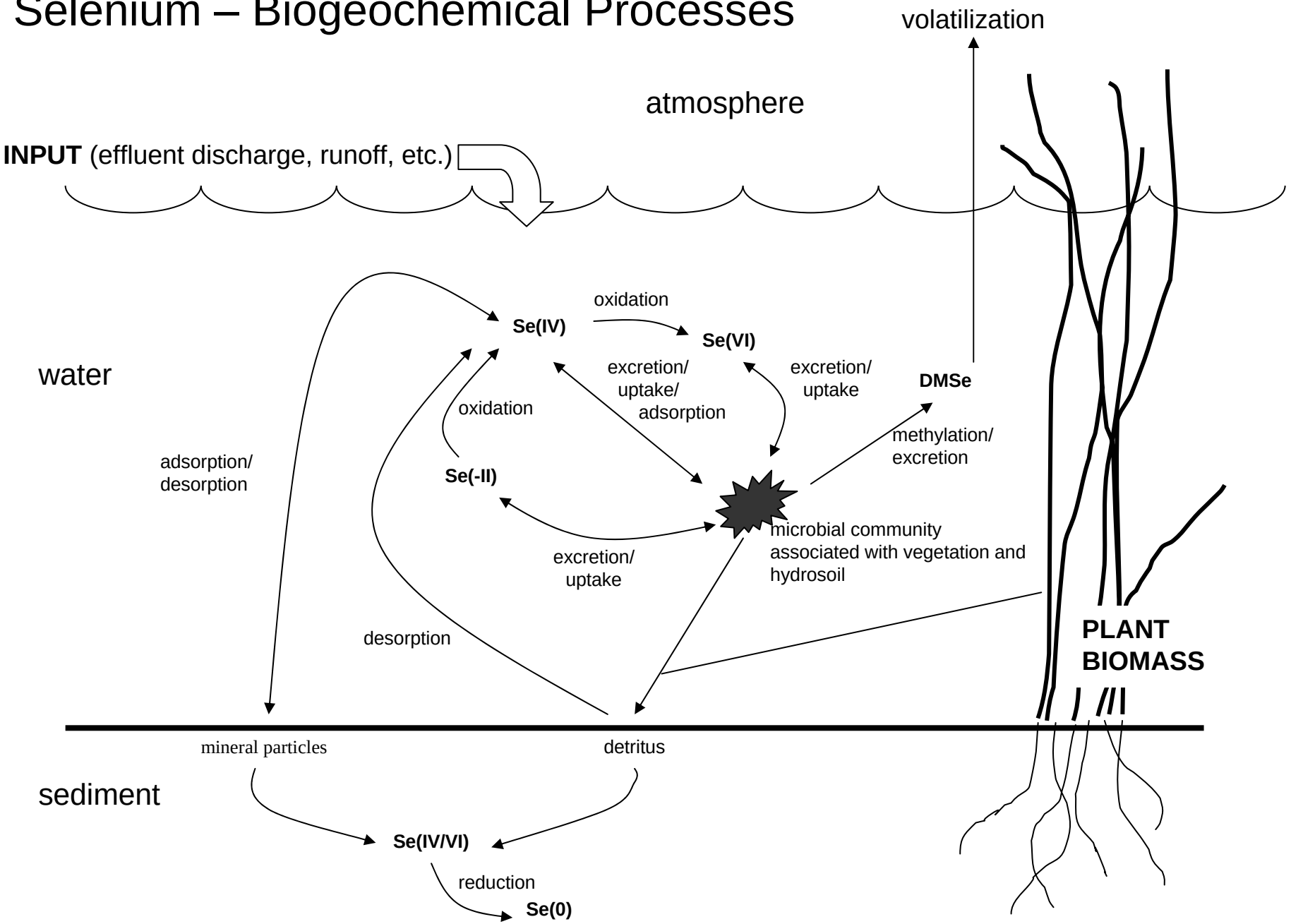
80
Hg
200.59

34
Se
78.96

Mercury – Biogeochemical Processes



Selenium – Biogeochemical Processes



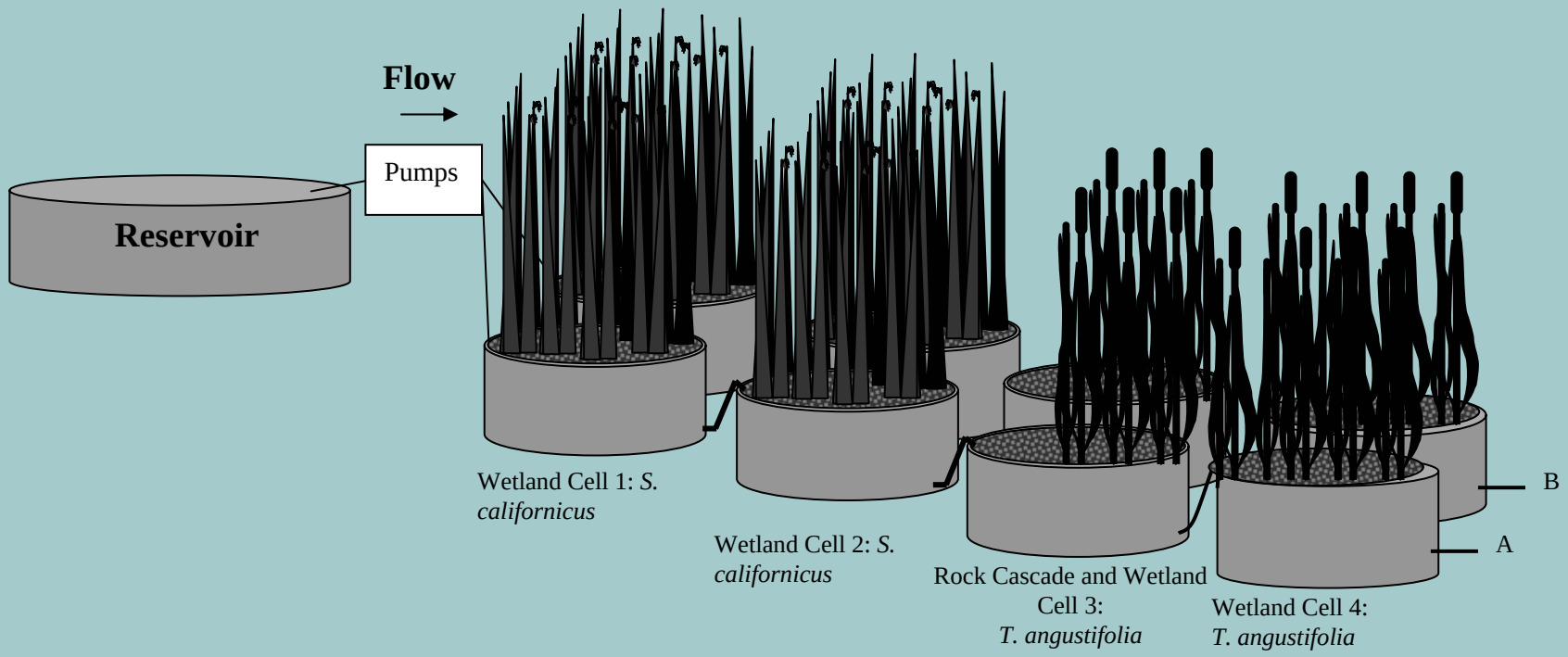
Constructed Wetland Treatment System Treatment Strategy for Targeted Constituents

Targeted Constituents	Treatment Strategy
Hg	Mercury stabilization in sediment (sorption and reduction) Sorption to OC and CEC Hg + S $\rightarrow$ HgS (mercuric sulfide, cinnabar) > S:Hg and ~ -200 mV
Se	Selenium stabilization in sediment. Reduce Se to Se^0 (ferroselenite, seleniferous pyrites)

Key Concepts

- Goal is to remove targeted constituents from aqueous phase and partition these to sediments in non-bioavailable forms.
- Plants provide organic matter that supplies carbon and energy source for sulfate-reducing bacteria.
- Performance is evaluated by decrease in aqueous concentrations and in toxicity measured in upstream and downstream samples and in inflow and outflow of pilot-scale wetland cells.

Pilot-Scale Constructed Wetland System to Treat FGD Wastewater



FGD Constructed Wetland Pilot-Scale System

FGD Wastewater Experimental Design

- Simulated FGD wastewater
- Actual FGD wastewater
- Actual amended FGD wastewater
- Pilot-scale scrubber wastewater

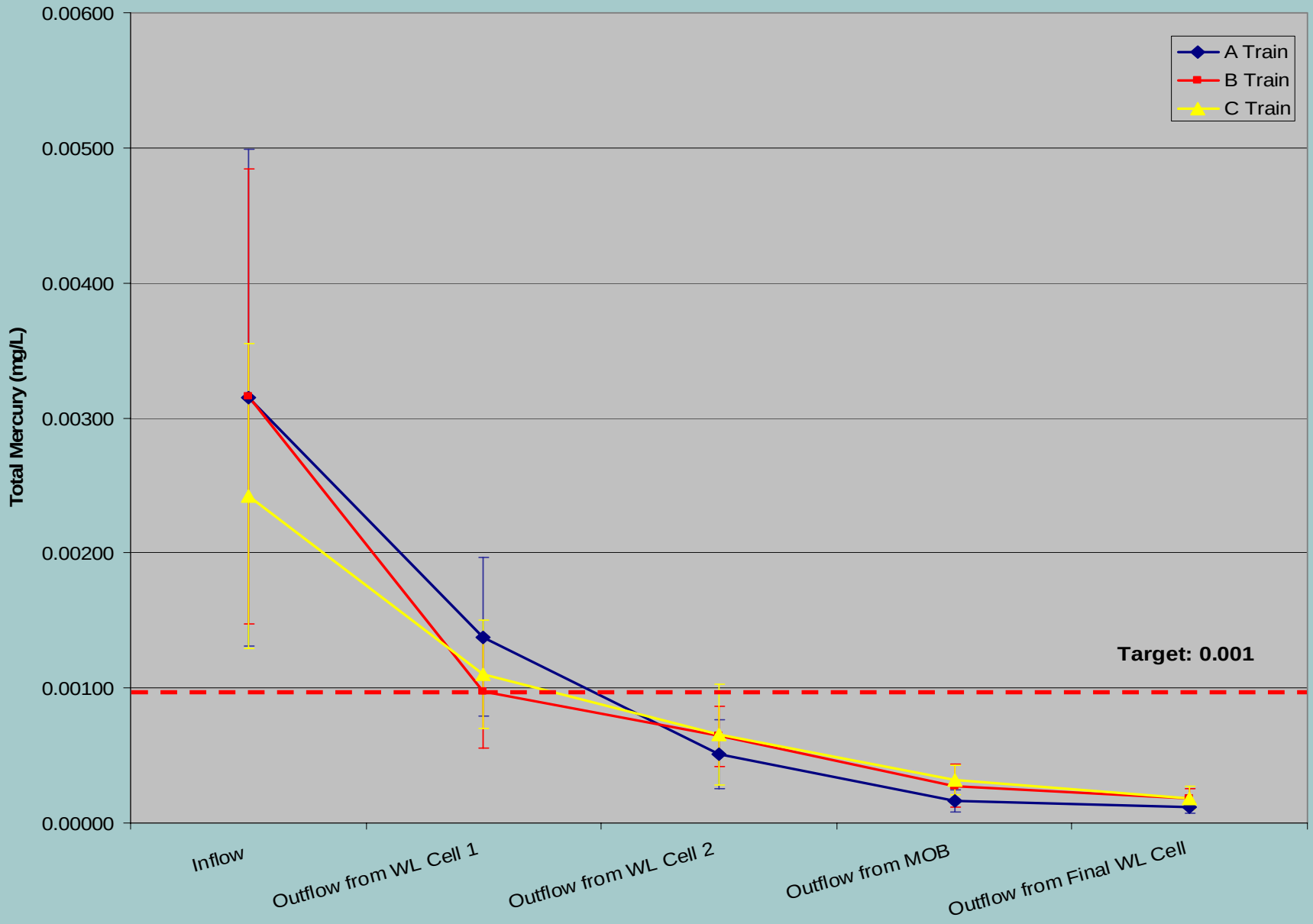
FGD Pilot Scrubber

FGD Wastewater Characteristics

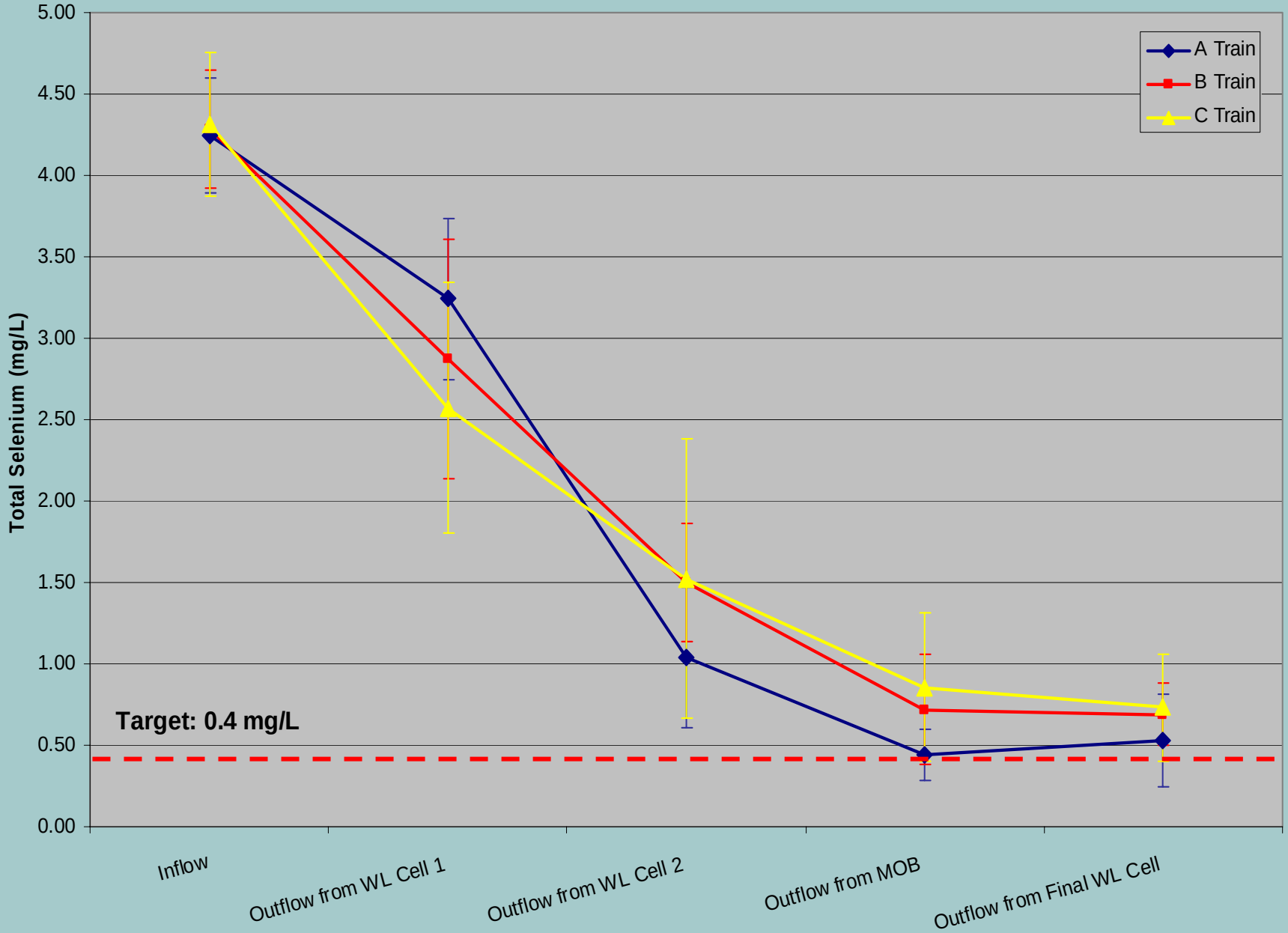
	Simulated FGD Wastewater		Actual FGD Wastewater	Actual FGD Wastewater Amended	Pilot Scrubber Wastewater	Target Outflow
	Conc. (mg/L)	Source	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Mercury	0.02	$Hg(NO_3)_2$-H_2O	<0.0002	0.2*	0.0004 - 0.0432	0.001
Selenium	7.4	$NaSeO_4$	0.15	2*	0.61 - 2.98	0.4
Arsenic	0.28	$NaAsO_2$	0.0064	0.0064	0.0047 - 0.1012	
Chloride	12,500	$CaCl_2$, $MgCl_2$-$6H_20$	9,300	9,300	3150 - 4225	
Sulfate	3,000	$CaSO_4$	1645	1645	1245 - 1611	
COD	100	Dibasic Acid	938	938	268 - 693	
TSS	1,000	Flyash	25	25	6 - 356	

* Amended concentrations.

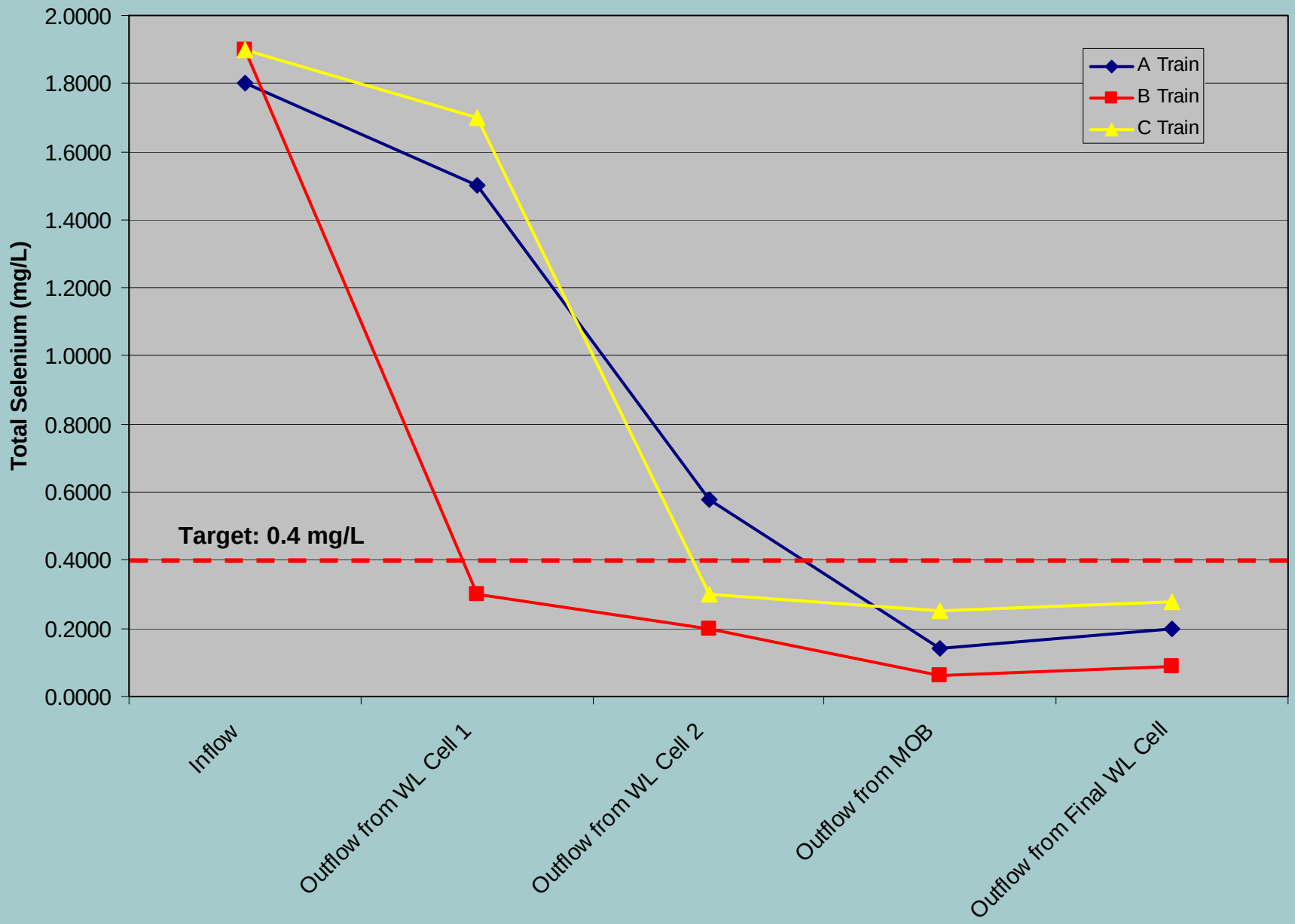
Mercury (Simulated FGD Wastewater)



Total Selenium (Simulated FGD Wastewater)



Total Selenium (Actual FGD Wastewater)



Toxicity

- **With transformation of Hg and Se and co-management of chlorides, no aqueous toxicity observed for:**
  - ***Ceriodaphnia dubia* (survival, reproduction)**
  - ***Hyalella azteca* (survival, growth)**
- **Both sediments and detritus are toxic initially to *H. azteca* (survival, growth). However, toxicity diminishes over time.**

Conclusions

- **Ecological risk mitigated**
  - **Pilot-scale CWTS achieved target Hg (0.001 mg/L) and Se (0.4 mg/L) levels for compliance with NPDES requirements.**
  - **No aqueous toxicity observed in final effluent.**
- **Targeted constituents in FGD wastewater are being treated successfully for discharge or reuse.**
- **The pilot CWTS is providing removal rate coefficients for Hg and Se and full-scale design parameters.**